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TEST AND EVALUATION OF THE NAVY TECHNICAL INFORMATION PRESENTATION SYSTEM (NTIPS) AN/SPA-25D FIELD TEST RESULTS

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This document describes the results of the second Field Test of Navy System-related Technical Information (TI) developed by the Navy Technical Information Presentation System (NTIPS). Three types of experimental TI were compared with the conventional Technical Manual. For performing troubleshooting tasks, the NTIPS electronically displayed automated troubleshooting TI (called Fault Isolation by Nodal Dependency, FIND) was compared with the conventional Technical Manual and for performing corrective maintenance, NTIPS electronically displayed TI was compared with NTIPS on paper and the conventional Technical Manual.

Tests were carried out at the Naval Sea Combat Systems Engineering Station in Norfolk, Va. using two operational AN/SPA-25D radar repeaters (with introduced faults). Test subjects were Electronic Technicians stationed on ships and at shore based facilities in Norfolk, Va.

All test objectives were achieved. Almost all (92%) of the subjects perferred

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All test objectives were achieved. Almost all (92%) of the subjects preferred electronically delivered TI to the conventional Technical Manual. They were able to use NTIPS TI to troubleshoot more accurately and with greater speed, than with the conventional Technical Manual. For corrective maintenance, subjects performed at the same accuracy and speed regardless of the TI type.

ADMINISTRATIVE INFORMATION

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Many personnel from the Display/Distribution Branch deserve special credit. Particular acknowledgement is due to Alan Mills, Chief of the Display/Distribution Branch, for his efforts in coordinating the test and in scheduling test subjects. The two test coordinators, Edgar Reinhold and Edward Corder assisted in selecting troubleshooting problems, in inserting faults into the equipment, and in monitoring technicians and equipment safety throughout the test. Their efforts provided the basis for an efficient and smoothly run test and we are especially grateful for their dedication and support. Finally, Millard Thomas, an engineer with the Display/Distribution Branch, provided valuable assistance in selecting and describing the troubleshooting problems used in the test.

Special credit is due to LCDR James Dietz, ETCM Robert Dunn, and ET1 Robert Lundien all of COMNAVSURFLANT for their assistance in selecting and scheduling the 24 test subjects. All of the technicians who gave of their time to serve as test subjects did so conscientiously and with great attention to detail. These technicians included both shipboard personnel (USS Fairfax County, USS Dahlgren, USS Iwo Jima, USS Nashville) and shore-based personnel (Naval Telecommunications Center, Fleet Training Center, COMNAVSURFLANT).

Our thanks also go to Leonard Basil of the David Taylor Research Center for his support as Test Director and to Donnie Hill and Harry Friedman of the David Taylor Research Center Photographic Laboratory for their excellent video work.

1.0 TEST SUMMARY

1.1 BACKGROUND AND PURPOSE

This is the second of two operational field tests of the Navy Technical Information Presentation System (NTIPS), a system that has been designed to improve the quality and reduce the difficulty and expense of acquiring and managing Technical Information (TI) for logistic support of Navy weapons systems. NTIPS maximizes reliance on automated systems, starting with documentation specifications and authoring procedures, and culminating in the electronic delivery of TI to the technician at the maintenance site. NTIPS is currently in Phase III: Test and Evaluation. Both tests were designed to compare TI generated using NTIPS procedures with conventional paper technical manuals used for performing troubleshooting and corrective maintenance. The test tasks in the first test were performed on the Rudder Manual Trim System of the F-14A at Naval Air Station, Miramar, California.[1] The SPA-25D radar repeater was used in the second test which was conducted at the Naval Sea Combat Systems Engineering Station, Norfolk, Virginia. Both systems were selected by NTIPS staff from a list of candidates prepared by the Naval Technical Manual Management Policy Council.

During the spring of 1987, a test plan was developed[2] for the field test using the AN/SPA-25D radar repeater. A pretest of the plan was conducted in June 1987 at the Naval Sea Combat Systems Engineering Station and the plan was modified in August 1987. The full test was conducted in September. The objectives of the field test were as follows:

- o Compare the performance of enlisted maintenance technicians using the TI prepared under NTIPS procedures with the performance of technicians using conventional TI (the conventional paper Technical Manual for the AN/SPA-25D).
- o Compare technicians' performance when guided by TI printed on paper versus TI presented via an electronic medium.

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1. Test and evaluation of the Navy Technical Information Presentation System (NTIPS): F-14A Experimental Technical Information Field Test. June 1987 (Essex Corporation)

2. NAVY TECHNICAL INFORMATION PRESENTATION PROGRAM. Phase III Test and Evaluation of the Navy Technical Information Presentation System. AN/SPA-25D Experimental Technical Information Test Plan. August 1987 (Essex Corporation)

- Establish which design characteristics of NTIPS TI are most effective or least effective in an operational situation.
- Assess user acceptance of certain features of the NTIPS (medium, content, format, and style) TI presentation.

All of these objectives were achieved. This section provides an overview of the test design, test execution, and test results. This field test of NTIPS TI, was performed using off-the-shelf electronic delivery devices. The test was not designed to evaluate fielded hardware, but rather to test NTIPS approaches to creating and electronically displaying TI that is expected to be intrinsically more effective than conventional TI, thus reducing fleet reliance on paper manuals. In addition, the test was designed to provide guidance in establishing areas of needed improvement to the TI and the TI electronic delivery device, as well as to demonstrate the current effectiveness of the NTIPS approaches.

1.2 TEST SITE AND TEST PERSONNEL

The field test was conducted at Naval Sea Combat Systems Engineering Station, Norfolk, Virginia in the test bay area. The test utilized two operational AN/SPA-25D radar repeaters. The test subjects were 24 active-duty Electronic Technicians (ETs) made available by the Commander Naval Surface Forces U.S. Atlantic Fleet (COMNAVSURFLANT). For test purposes these technicians were assigned to experienced and inexperienced groups, based on the length of time they had spent performing maintenance on radar systems and other electronic equipment; those with over one year of experience were assigned to the experienced group, the others were assigned to the inexperienced group. There were 11 experienced technicians and 13 inexperienced technicians.

In addition to test subjects, the following personnel were required for the test: two test coordinators from the Combat System Engineering Station; a Test Director, 2 computer analysts and a video crew from David Taylor Research Center; a computer specialist from Hughes Aircraft; and three data collectors from Essex Corporation.

1.3 SCOPE OF THE TEST

The field test was conducted using two operationally realistic troubleshooting tasks and three corrective maintenance tasks. As the basis for the troubleshooting tasks, faults were introduced into the AN/SPA-25D repeaters by the test coordinators. For each fault, test subjects were asked first to verify the fault and then to isolate it. On Fault 1, half of the test subjects used the electronic display system (Fault Isolation by Nodal

Dependency - FIND) and half used the conventional Technical Manual. Those who used the electronic display for Fault 1 used the conventional Technical Manual for the task involving isolation of Fault 2 and vice versa. FIND is an automated troubleshooting procedure designed to lead the technician through fault isolation. All subjects performed three corrective maintenance tasks, each with a different type of TI: NTIPS presented electronically, NTIPS in a paper medium and the conventional Technical Manual. The assignment of TI to corrective maintenance tasks was counterbalanced across the subjects.

Effectiveness of the types of troubleshooting and corrective maintenance TI were compared by evaluating the performance of technicians using each type of TI. Performance measures included the time required for successful completion of the task, and the number of errors committed by technicians during task performance. These measures were supplemented by the subjects' own evaluations, obtained by questionnaire and interview, of the operational justifiability, usefulness and effectiveness of each type of TI for performing troubleshooting or corrective maintenance.

1.4 TEST EVENTS

Once preparation of the experimental TI was completed, the field test consisted of the following events:

1. Dry Run, May 1987. The proposed Test tasks and the experimental TI were checked out by senior technicians from Clifton Precision, Incorporated, manufacturer of the AN/SPA-25D, on-site at the Naval Sea Combat Systems Engineering Station.
2. Pretest, 29 June-1 July 1987. During this event, each of four ETs performed one of the troubleshooting tasks and either the three removal or the three replacement tasks used in the Test to evaluate the experimental TI generated for the Field Test. All three types of TI were checked. As a result of this event, a number of changes were made to the NTIPS TI and to the test plan.
3. Field Test, 8-24 September 1987. The performance of 24 ETs was measured while they performed troubleshooting and corrective maintenance tasks using NTIPS TI and the conventional Technical Manual. For corrective maintenance, the NTIPS TI was presented both electronically and on paper. NTIPS troubleshooting TI was presented only electronically. Technicians also provided preference and rating information on a questionnaire and in a post-test debriefing.

1.5 CONDUCT OF THE FIELD TEST

Test subjects for the Test were 24 ETs, 11 experienced and 13 inexperienced. After an instruction session on the Test and on the use of the electronic delivery device for both troubleshooting and corrective maintenance, Test personnel asked subjects to solve the first troubleshooting problem and assigned either NTIPS FIND or the conventional Technical Manual as the TI to be used. Following completion of the first problem, Test personnel gave the subjects a second troubleshooting task, and supplied them with the TI type they had not used for the first problem. When both troubleshooting problems were completed, each subject filled out an evaluation questionnaire comparing the two types of TI. The second part of the test involved the performance of three corrective maintenance tasks by each technician using a different type of TI (conventional Technical Manual, NTIPS Electronic Delivery, and NTIPS Paper) for each task. At the end of the test, an evaluation questionnaire comparing the TI used for corrective maintenance was completed by each technician and Test personnel conducted an interview. During troubleshooting and corrective maintenance performance, Test personnel recorded both performance time and errors committed (for each step). A detailed description of the Test Plan is shown in Table 3.

1.6 SUMMARY OF TEST RESULTS

All test objectives were accomplished. Careful observation of technician performance on several types of tasks using conventional Technical Manuals and NTIPS TI, both electronic-delivery and paper presentation, showed the following:

1. For troubleshooting tasks. The inexperienced technicians' performance time was 26% faster with FIND than when using the conventional Technical Manual; the experienced technicians' performance time was 22% faster with FIND. These performance time improvements could be increased if the time spent waiting for the system to respond was reduced. At the present time, 60% of the technicians' TI use time is spent in waiting for the next screen.

2. For troubleshooting tasks. All technicians were given 15 minutes to initiate some testing or action judged to be relevant to isolating the fault. Technicians who were not able to do so were told how to start, e.g., were given significant assistance. All technicians using FIND isolated the fault without significant assistance. Only 58% of the technicians using the conventional Technical Manual isolated the fault without signficant assistance; the remaining 42% had to be told to use the Fault Logic Diagram, a presentation which steps through a complete or partial fault isolation.

3. For troubleshooting tasks. Some technicians needed minor help while performing work relevant to isolating the fault. Test personnel

prompted these technicians (e.g., helped interpret a waveform) as required. The number of prompts provided to technicians when using FIND was 7; when using the conventional Technical Manual, 39. When using the conventional Technical Manual, experienced technicians were given 15 prompts and inexperienced technicians were given 24 prompts.

4. For corrective maintenance tasks. Performance times for all three types of TI (NTIPS electronically delivered, NTIPS on paper, and conventional Technical Manual) were essentially the same. Additionally, there were no significant differences between performance times of experienced and inexperienced technicians.

5. For corrective maintenance tasks. Inexperienced technicians committed the greatest number of errors when using the conventional Technical Manual; experienced technicians committed the greatest number of errors when using NTIPS delivered electronically. Eighty-seven percent of these errors made by experienced technicians can be attributed to inadequate graphics. Experienced technicians made 23% fewer errors than inexperienced technicians.

6. Technician preference. All 24 technicians preferred FIND to the conventional Technical Manual for troubleshooting. The primary reasons given were the step-by-step text instructions and the integration of text and graphics in FIND. For the step by step text instructions in the corrective maintenance TI, 63% of the technicians preferred NTIPS electronic delivery, 17% preferred NTIPS on paper and 20% preferred the conventional Technical Manual. Experienced technicians preferred the graphics presented in NTIPS paper and inexperienced technicians preferred the conventional Technical Manual graphics.

1.7 TEST CONCLUSIONS AND TECHNICIAN RECOMMENDATIONS

With the cooperation of COMNAVSURFLANT and the Naval Sea Combat Systems Engineering Station, the NTIPS Field Test achieved all test objectives. Based on Test data the following conclusions have been reached:

1. Technical Information presented electronically represents a distinct improvement in the eyes of fleet technicians engaged in maintenance of electronic equipment. This result applied particularly to troubleshooting and was obtained even with the use of off-the-shelf, non-portable computers which were not optimally designed for operational use, and with graphics which were clearly in need of much improvement.

2. NTIPS presentations of troubleshooting TI were shown to result in significant improvements in fault-isolation effectiveness and performance time.

3. NTIPS presentations of corrective-maintenance TI did not lead to significantly reduced test performance time of either experienced or inexperienced technicians. For inexperienced technicians, the number of errors committed during the corrective maintenance procedures were reduced.

4. Two major weaknesses were identified in the NTIPS TI. The graphic presentations in the corrective maintenance TI were difficult for technicians to use in identifying and locating the parts called out in the step by step text instructions. The system's response time for the NTIPS troubleshooting was slow. Improvements in these two areas might significantly increase the usability of NTIPS TI.

Test personnel and subject technicians provided valuable recommendations during the test. For example: it was made clear that the quality of graphics in any future uses of electronic presentation must be much improved over that of the graphics used in the test. This improvement would involve modifications in the current design of the graphic, in graphic size, and in graphic resolution. Technicians' comments also demonstrated the need for greater flexibility in the automated TI presentations to permit experienced technicians to move more rapidly through a series of steps without the time-consuming necessity of continually viewing material they already know from experience. Technicians also suggested use of animation to portray the correct waveform for troubleshooting.

Detailed results of the tests and specific recommendations of the test personnel are discussed in Section 4.0.

1.8 ORGANIZATION OF TEST REPORT

Section 2 describes the preparation and review of the experimental TI (electronic presentation and paper) used for the test. Section 3 describes the actual tasks selected for testing and summarizes the Test design, which was independently published as a DTRC report (ref. 2). As described in Section 3, the initial Test Plan was modified to some extent as a result of the Pretest Trials discussed previously. Section 4 discusses in detail the test results and summarizes performance times, performance errors, and other results obtained by monitoring the Test task performances of technicians using the five kinds of TI tested. Section 4 also includes the subjects' preferences and their recommendations for improving NTIPS TI and its electronic presentation. Section 5 summarizes the Field Test and presents overall conclusions. Appendix A contains the actual forms used for data collection. Appendix B shows the preference questionnaire administered to the 24 Test subjects. Appendix C contains samples of the TI tested.

2.0 PREPARATION AND APPROVAL OF EXPERIMENTAL AND CONVENTIONAL TI

This section discusses the generation of the experimental NTIPS TI used for the Test (2.1), the review of this TI for test suitability (2.2), and the review of conventional TI for compatibility with the NTIPS TI (to insure that it covered the same tasks) (2.3).

2.1 GENERATION OF EXPERIMENTAL TI

The experimental TI was prepared by Clifton Precision Incorporated, manufacturer of the AN/SPA-25D Radar Repeater. In order to prepare the TI for test purposes, Clifton Precision was provided a MODCOMP computer which hosted the NTIPS prompted automated authoring system, a terminal, a screen printer, and a modem which permitted communication with a similar MODCOMP at Hughes Aircraft Company for obtaining assistance when problems arose. Clifton Precision personnel were trained by Hughes in operation of the authoring system and in inserting system signal-dependency information into the FIND automated troubleshooting program.

NTIPS specifications provided to Clifton Precision for use in preparing the experimental TI included general content, format, and style specifications covering the following TI characteristics:

a. Procedures
b. Descriptive information
c. Illustrations
d. Style (general)
e. Numbering, indexing, and how-to-use information
f. Diagrams.

Also provided was the NTIPS specification entitled "Fault Isolation by Nodal Dependency (FIND): Troubleshooting Equipment, Software, and Products" to permit generation of electronically displayed troubleshooting information. FIND is an interactive system that selects a series of optimal test points based on a network of component interdependencies, component failure rates, and time-to-test requirements. The technician enters fault symptoms which the FIND software uses to identify the first test point; the test results from the first test provide FIND with the information to select the next, most logical test point. This sequence continues until FIND isolates the fault. Procedural instructions and supporting graphics are provided to the technician for each test point.

The above specifications are all draft documents prepared under NTIPS, and are now being circulated among the System Commands for comment and possible adoption.

Before delivery of the experimental TI was made to NTIPS, Clifton Precision personnel validated the draft TI with the use of an operational AN/SPA-25D made available by Naval Sea Combat Systems Engineering Station. Validation consisted of a technical-accuracy review by subject-matter experts based on comparing the NTIPS TI against the AN/SPA-25D hardware. Reviews to assure that the experimental TI was in compliance with NTIPS specifications for content and style were performed by Clifton Precision, by Hughes Aircraft Company, and by the NTIPS office.

Observations made by Clifton Precision during preparation of the experimental TI were recorded in detail in a Journal format (a Log), and these data will be evaluated to establish the possible need for NTIPS modifications. Certain changes to the NTIPS-designed authoring system and to the electronic-display system have, in fact, already been carried out as a result of Clifton's experience.

Experimental TI was generated for the following AN/SPA-25D troubleshooting and corrective maintenance tasks:

- o A brief fault verification procedure in a text format. Verification of a fault produces the fault symptoms required for entering the fault isolation procedure.
- o Troubleshooting TI implemented on the FIND system. This TI was used to isolate the faulty component producing a failure in (1) the sweep resolver and (2) the main gate generator. The only delivery medium for FIND TI is electronic display using (in this test) a cathode-ray tube.
- o Corrective-maintenance procedures (both electronic display and on paper) for the replacement (removal of a component, and installation of a new component) and check and adjustment of the focusing coil and azimuth resolver baseplate.
- o TI procedures (both electronic display and on paper) for all supporting tasks involved in readying the AN/SPA-25D for maintenance, such as indicator setup for maintenance, restoring the radar repeater to a ready condition and an illustrated parts breakdown (IPB) for relevant parts.

In accordance with NTIPS procedures, Clifton Precision generated the experimental TI in a single electronic data base, which was output in both paper and electronic-delivery format by Hughes Aircraft during a mastering process. In the Test, NTIPS troubleshooting TI was delivered electronically by an AT&T 3B-2/300 computer with an AT&T PC 6300 serving as the subject's interactive terminal. The subject entered

commands via the 6300's touch screen or keyboard. The terminal weighs approximately 40 pounds. The cathode-ray display (green) of the 6300 terminal has a screen size of 9.5 x 7 inches and a resolution of 640 x 400 lines. For corrective maintenance, a Zenith 248 personal computer was used. The Zenith monitor is 8 X 10", has a resolution of 640 X 350 lines, and has a color display. The terminal weighs approximately 40 pounds. When implemented, the NTIPS display system will consist of a single, militarized portable device which will weigh approximately 10 pounds, with dimensions of 12" x 9" x 2", with a screen size of 6.4" x 9.6", and with a resolution of 640 lines x 960 lines.

Except for FIND troubleshooting TI, the TI described above was provided in paper form as well as electronic-delivery form.

2.2 UPGRADE OF NTIPS TI

The evaluation of the NTIPS TI for the AN/SPA-25D is the second of two Field Tests, the first being conducted at the Miramar Naval Air Station, San Diego, CA on the F-14A Aircraft. Lessons learned from the F-14A Test were applied to upgrade the NTIPS TI for the AN/SPA-25D. Two major improvements made to the AN/SPA-25D TI concerned the locator graphics and test set-up instructions in the FIND TI, and the time required for the system to display corrective maintenance TI. Each improvement is summarized below.

a. FIND Text Graphics. Observation of the fault isolation performance during the F-14A Test and during the AN/SPA-25D Pretest indicated improvement possibilities for two aspects of the FIND TI: (1) text instructions for setting up test equipment, the oscilloscope in the case of the AN/SPA-25D; and (2) graphics to aid the technician in performing tests. For the AN/SPA-25D these improvements, developed by technical personnel at the DTRC, involved card locators, test point locators, and waveform graphics (See Appendix C).

b. System Response Time for Displaying TI. The preference data collected from the technicians participating in the F-14A NTIPS Test indicated a strong objection to the long waits for the NTIPS device to display its TI. Technical personnel at the DTRC rehosted corrective maintenance TI to a Zenith 248 computer and its display terminal. This device provided response times which were considerably faster than the device used to deliver NTIPS TI during the F-14A Field Test.

2.3 REVIEW AND APPROVAL OF EXPERIMENTAL TI BY NTIPS

The acceptability of the experimental TI was based on a detailed review performed by NTIPS personnel and contractor organizations (Hughes Aircraft and Essex Corporation). This review was supplemented by a final on-site validation at Naval Sea Combat Systems Engineering Station in which the procedures and graphics were checked by Clifton Precision personnel against an operational AN/SPA-25D. A review by NTIPS personnel established that the draft TI complied with the NTIPS style, content, and format specifications. The validation performed in the field assured that the experimental TI contained all information needed by the technicians, that this information was accurate, and that it was presented as clearly and simply as possible. Problems identified by these reviews were documented and corrected by Clifton Precision or Hughes Aircraft.

3.0 TEST DESIGN

3.1 TEST PERSONNEL

The NTIPS AN/SPA-25D Test was conducted during the period September 8 to September 24, 1987 in close coordination with the Naval Sea Combat Systems Engineering Station, Norfolk, VA. Actual performance of the test tasks took place in the test bay area of the Station. A listing of test personnel and their functions is shown in Table 1. Test coordination, technical consultation, equipment check-out, and fault insertion were provided by technical personnel of the Naval Sea Combat Systems Engineering Station. Test subject selection and assignment was accomplished by Naval personnel stationed at COMNAVSURFLANT. Detailed test scheduling was performed by management personnel at the Naval Sea Combat Systems Engineering Station. Twenty-four technicians from Norfolk-based ships or from local shore-based facilities participated as test subjects. These subjects performed troubleshooting and corrective maintenance tasks as specified in the Test Plan (3.3); responded to a preference questionnaire designed to evaluate the strengths and weaknesses of NTIPS TI as compared to conventional paper Technical Manuals; and provided comments during debriefings.

The test was supervised by a Test Director from David Taylor Research Center. The Test Director coordinated the Test with personnel from the host station; provided technical direction on test performance; and ensured that the test was conducted smoothly and on schedule. The Test Director was supported by (1) three computer specialists, two from David Taylor Research Center and one from Hughes Aircraft Company, (2) three data collectors from the Essex Corporation, and (3) a video camera crew from David Taylor Research Center. The computer specialists briefed subjects on the use of the electronic delivery devices and the NTIPS TI; and assisted with the operation of the delivery devices as needed throughout the test. The data collectors presented test briefings and debriefings, recorded performance times, errors, and activities for each maintenance task, and administered the preference questionnaire. The video crew taped samples of troubleshooting and corrective maintenance task performance and debriefing sessions for 12 of the subject technicians.

Table 1. Test personnel and functions

Source of Test Personnel	Functions
Naval Sea Combat Systems Engineering Station	
o Management Personnel	o Coordinated subjects and facilities, accomplished detailed scheduling
o Technical Personnel	o Inserted faults for troubleshooting problems
	o Checked-out equipment following each test performance
	o Monitored subject-technician performance for safety
COMNAVSURFLANT	o Arranged for subject-technicians to participate in the test
Naval Ships and Shore-Based Facilities	
o 24 Electronic Technicians as test subjects	o Performed test tasks using conventional Technical Manual and FIND for troubleshooting; and the conventional Technical Manual, NTIPS TI electronically delivered and NTIPS TI on paper for corrective maintenance
	o Responded to preference questionnaire and post-test debriefing
David Taylor Research Center	
o Test Director	o Served as principal NTIPS representative
	o Directed the test
	o Coordinated test with COMNAVSURFLANT and host station personnel

Table 1 (Continued)

Source of Test Personnel	Functions
o Computer Specialists	o Briefed subject technicians on the use of computers and the NTIPS TI o Maintained computers used for electronic delivery of TI o Maintained and modified software as needed
Hughes Aircraft Company o Computer Specialist	o Briefed subject-technicians on the use of computers and NTIPS TI o Maintained computers used for electronic delivery o Maintained and modified software as needed
Essex Corporation o Data Collectors	o Presented test briefings describing the test's purpose and procedures o Collected data on subject-technician activities, performance times, and errors o Conducted debriefings of subjects and administered preference questionnaires o Analyzed data and prepared test report

3.2 MAINTENANCE TASK DEFINITION

Test subjects performed two troubleshooting tasks and three corrective maintenance tasks on the AN/SPA-25D Radar Repeater using different types of Technical Information. The AN/SPA-25D is a general-purpose Plan Position Indicator (PPI) designed for remote display of azimuth and range information for targets detected by a radar set. Target bearing is determined by means of an electronic cursor; target range by means of a range strobe. The range strobe can be used either as a video strobe, appearing as a ring on the video sweep, or as a cursor strobe appearing as a brightened spot (marker) on the electronic cursor. Range rings are provided for estimating the range of targets without using the range strobe. The display range of the indicator is variable continuously from 1 to 300 miles consistent with the pulse repetition frequency (prf) of the input. The indicator will operate with prfs from 10 to 5,000 pulses-per-second (pps). The AN/SPA-25D contains an azimuth-range indicator with an attached air cooler. The repeater includes four functional sections: timing, sweep, brightening, and power supply.

Two faults were selected for the troubleshooting tasks; one in the main gate generator card and the other in the sweep resolver. The fault in the main gate generator was a disconnected capacitor which resulted in a blank scope. The sweep resolver fault introduced by taping over a terminal, led to the disappearance of the North-South sweep. The sweep resolver fault was introduced first, and the subject technicians were directed to proceed through fault verification and fault isolation. Once the sweep resolver fault was isolated (the faulty component determined), the first fault was removed and the second fault was introduced (lifting the capacitor on the main gate generator). The subject technician then verified and isolated this fault.

The corrective maintenance tasks selected for the Test included removal and installation of the variable delay line, of circuit card assemblies, and of support brackets. These are three of the subtasks involved in performing maintenance on the Tube Focusing Coil. Several criteria were used in selecting these tasks. They are:

- Tasks must be capable of being performed in an operational context represented by the maintenance facilities of an organizational-level maintenance shop.
- Tasks must be presented in a way that conforms to procedures and methods normally used in an operational setting.
- Tasks must be capable of being performed by the type of technicians called for in typical maintenance operations.
- Performance of the tasks must not require support effort for which NTIPS TI is not available.
- A task should be neither too simple nor too complex. The former would provide inconclusive results, and the latter would require too lengthy an overall test schedule.

Both the troubleshooting and corrective maintenance tasks selected for the Test were determined to be representative of maintenance tasks regularly performed on the AN/SPA-25D radar repeater. Table 2 presents a typical maintenance sequence; the tasks used in the test were selected from this sequence.

3.3 TEST PLAN AND SUBJECTS

The Test was designed (ref. 2) so that comparisons could be made based on the technicians' performance using each type of TI. Five combinations of tasks and TI materials were compared. For troubleshooting there were two types of TI material: NTIPS electronically displayed FIND and conventional Technical Manual (Conv(P)). For corrective maintenance the TI materials were NTIPS electronically displayed (NTIPS (E)), NTIPS on paper (NTIPS (P)), and conventional Technical Manual (Conv(P)). Appendix C provides examples of each type of TI. Table 3 shows the plan for assigning 24 subjects (12 experienced and 12 inexperienced) to combinations of TI types and maintenance tasks. Experienced (EXP) subjects were defined as those technicians who had more than one year of experience on maintenance of radars or related electronic equipment; inexperienced subjects (INEXP) had less than this. All subjects were Electronic Technicians (ETs).

According to the Test Plan (ref. 2) half of the 12 subjects in each experience group would perform troubleshooting using FIND for Fault 1 and the conventional Technical Manual for Fault 2 — the remaining six subjects would perform troubleshooting on Fault 1 with the conventional Technical Manual and on Fault 2 with FIND. Fault 1 was always performed first. For corrective maintenance, each of the three TI types was paired with each of three different task sets (1) remove/install variable delay line, (2) remove/install circuit cards, and (3) remove/install support brackets. Assignment of subjects to these combinations is shown in Table 3. Subjects used the same TI for installation that they used for removal (e.g., S1 uses NTIPS(E) to remove the variable delay line and then later to reinstall the delay line).

The test design as shown in Table 3 is reproduced from the Test Plan. As the Test progressed, some modifications were made in the Test procedure based on the availability of experienced subjects. In the actual Test, 11 experienced and 13 inexperienced subjects were used. Thus the Test included the following assignment of subjects to TI conditions and orders:

- Troubleshooting Fault 1:
  - FIND: 6 experienced; 6 inexperienced
  - Conv(P): 5 experienced; 7 inexperienced

Table 2. Identification and definition of troubleshooting and corrective-maintenance tasks

Task Title	Task Definitions
1. Ready AN/SPA-25D for Troubleshooting and Corrective Maintenance	Before any maintenance work can be done, certain safety, power, and system conditions must be set. Accomplishment of this task establishes these conditions.
2. Verify the Fault	The technician is told that a malfunction exists in the AN/SPA-25D. The technician selects the relevant TI and follows its instructions to verify that the reported malfunction does in fact exist. (In this test, an appropriate fault has actually been inserted into an operational radar repeater by engineers of the Naval Sea Combat Systems Engineering Station to assure a realistic procedure.) Fault symptoms resulting from fault verification serve as the basis for entering the FIND automated troubleshooting system or the troubleshooting part of the conventional Technical Manual.
3. Troubleshoot to Isolate Faulty Component	In this task the technician follows the troubleshooting instructions of his TI in order to identify the component causing the fault symptom; i.e., to perform fault isolation. For the NTIPS TI, these step-by-step troubleshooting instructions are called FIND (Fault Isolation by Nodal Dependency). The technician obtains these instructions by interacting with the NTIPS electronic delivery device.
4. Remove Faulty Component	The technician begins the process of correcting the malfunction by removing the component which his testing has identified as faulty.
5. Install a New Component	After obtaining a working component from Supply, the technician installs it in the system in place of the faulty component he has removed.

Table 2 (Continued)

Task Title	Task Definitions
6. Conduct Operational Check	The technician performs an operational check of the radar repeater to verify that preceding actions (1) have eliminated the malfunction and (2) have not introduced a new fault into the system.
7. Restore the AN/SPA-25D to Operational Condition	The technician will restore the radar repeater to operational readiness by eliminating conditions which were changed to permit maintenance.
8. Complete Maintenance Records	The technician will report the completed work on the appropriate Maintenance Action Report (2-KILO).

Table 3. Test design

SUBJECTS		TROUBLESHOOTING		CORRECTIVE MAINTENANCE		
EXP	INEXP	FAULT 1	FAULT 2	VARIABLE DELAY	CIRCUIT CARDS	SUPPORT BRACKETS
1	13	FIND	CONV (P)	NTIPS (E)	NTIPS (P)	CONV (P)
2	14					
3	15					
4	16					
5	17			NTIPS (P)	CONV (P)	NTIPS (E)
6	18					
7	19	CONV (P)	FIND			
8	20					
9	21			CONV (P)	NTIPS (E)	NTIPS (P)
10	22					
11	23					
12	24					

- o Troubleshooting Fault 2:
  - FIND: 5 experienced; 7 inexperienced
  - Conv(P): 6 experienced; 6 inexperienced
- o Corrective Maintenance: NTIPS(E); NTIPS(P); Conv(P)
  - 4 experienced
  - 4 inexperienced
- o Corrective Maintenance: NTIPS(P); Conv(P); NTIPS (E)
  - 3 experienced
  - 5 inexperienced
- o Corrective Maintenance: Conv(P); NTIPS(E); NTIPS(P)
  - 4 experienced
  - 4 inexperienced

The average experience level of experienced and inexperienced subjects is shown below. It can be seen that experienced subjects had an average of one and a half years experience with radar maintenance and a total of almost seven years experience in the Navy. The average for the inexperienced subjects was three months for radars and approximately three and a half years in the Navy.

Test subjects' experience and duty station

Technicians	Average Time		Number in Each Rate		
	In Navy	With Radar	E4	E5	E6
Experienced	6 yrs. 11 mos.	1 yr. 6 mos.	6	1	4
Inexperienced	3 yrs. 5 mos.	3 mos.	9	3	1

Duty Station

Ships:
USS Fairfax County (LST-1193)
USS Dahlgren (DDG-43)
USS Iwo Jima (LPH-2)
USS Nashville (LPD-13)

Shore Stations:
NTCC - Navy Telecommunications Center
FTC - Fleet Training Center
COMNAVSURFLANT

3.4 PRETEST EVENT

During the period 29 June-2 July, 1987, four ETs performed all maintenance tasks planned for the test. These efforts were carefully observed by test personnel to provide a basis for refining the Test Plan to assure that it was optimal for (1) efficient use of test subjects and observer personnel; (2) safe conduct of the tests; and (3) achieving the test objectives. The results of this pretest event were formally documented.[3]

The Pretest event thus constituted a verification of the experimental Technical Information, a vital process in the generation of all system-related TI required to assure the operational suitability (consistency with fleet procedures, technician capability, and operational environment) of the TI.

As a result of the Pretest event and additional trips to Norfolk:

1. Final changes were made to the experimental TI (including the addition of card locator, test point locator, and waveform graphics to FIND and the modification of the step by step test in FIND)
2. Logistic arrangements for test conduct were finalized
3. Final changes to the test procedure were incorporated to increase test efficiency.

3.5 TEST SCHEDULE AND PROCEDURE

The Test was conducted during the period from September 8 to September 24, 1987. One to three subjects performed the test tasks each day. Two AN/SPA-25D radar repeaters were made available by the Naval Sea Combat Systems Engineering Station, making it possible to test two subjects simultaneously. The schedule of events for each subject was:

- Attend a test briefing presented by an Essex Corporation data collector. This briefing covered the test purpose, the tasks to be performed, the estimated time required; and the importance to the program of filling out the preference questionnaire and participation in the debriefing.
- Attend a technical briefing presented by a Hughes Aircraft Company representative or a computer specialist from DTRC. This briefing covered FIND and the electronically displayed and paper versions of NTIPS TI for corrective maintenance. As part of this briefing the subject was given hands-on experience with the TI, the display device, the keyboard, and the touch panel.

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3 Naval Technical Information Presentation System: Initial Evaluation AN/SPA-25D Radar Repeater, August, 1987 (Essex Corporation)

- o Perform fault verification and troubleshooting using either FIND or conventional paper TI for Fault 1 and then using the other type of TI for Fault 2.
- o Fill out a questionnaire comparing FIND with the conventional Technical Manual for troubleshooting.
- o Perform corrective maintenance with each of the following TI types: NTIPS electronically delivered, NTIPS on paper, and conventional Technical Manual.
- o Fill out a questionnaire designed to obtain evaluative comments from the test subjects comparing effectiveness of NTIPS TI delivered by paper or electronically, and conventional Technical Manual for corrective maintenance.
- o Participate in a debriefing interview to evaluate the various TI forms and media used and their relative effect on the speed and accuracy of task performance. Provide opinions on new TI approaches.

3.6 THE ELECTRONIC DELIVERY DEVICE

The electronic delivery system used for troubleshooting tests was an AT&T 3B-2/300 computer with an AT&T 6300 terminal equipped with touch screen and keyboard. The touch screen worked by recording a signal when a finger interrupted the infrared beams which form a matrix across the front of the screen. When a pair of beams is broken by a finger passing through the matrix, the corresponding point on the screen is identified as being "touched." The computer terminal was hooked up to a printer.

The electronic delivery device used for the corrective maintenance TI was a Zenith Z-248. This system was chosen because its response time is much faster than the AT&T computer. Both computers and the printer were located on a cart near the radar repeater. To accommodate simultaneous testing on two radar repeaters, two sets of computers were also provided.

3.7 DATA COLLECTION CATEGORIES AND PROCEDURES

Data collection categories included: (1) two performance measures (performance time and errors committed during task performance), (2) one descriptive measure (actions engaged in by technicians during task performance), (3) technicians' subjective ratings (poor to excellent) of the quality of the text and graphics which made up the TI they used, and (4) technicians' preferences for electronic or paper presentation of TI. Sample data-collection forms for troubleshooting and for corrective-maintenance task performance are provided in Appendix A. The data collection form provides space to record the actions engaged in by the subject when performing each step in the procedure, the time to

perform each type of action, and any errors made by the subject. This form lists the task steps to be performed.

The subjects' actions during the conduct of the test tasks were codified as follows:

- o TI — Using Technical Information
- o C — Communicating
- o W — Performing work on the system
- o TI/C — Perusing TI and communicating at the same time (back and forth between perusing TI and talking)
- o TI/W — Perusing TI and working (actually moving or changing parts) at the same time — back and forth between TI and work
- o TI/E — Perusing TI and examining equipment (back and forth between TI and looking at equipment).

These categories were used in monitoring field test performance to provide a record showing what the subject did to complete each maintenance step. The procedure used was to record each action code while the corresponding action was occurring and to record the elapsed time until the subject went on to another type of action. Timing was initiated at the beginning of each subtask. Thus, within each subtask or step, it was possible to determine the amount of time spent working, examining equipment, perusing TI, etc.

The errors made by a subject were recorded as they occurred. Categories of errors included:

- o Makes False Starts: Begins to work on equipment, stops, looks back at TI, and then starts over.
- o Looks in Wrong Location: The subject attempts to find a component in a different location from the location listed in the step description.
- o Works on Wrong Part: The subject works on the wrong part or uses the wrong tool.
- o Other Errors: Errors not covered by the above defined categories.

Measures of performance time and accuracy were analyzed by subtask, by type of TI used, and by subject experience. The outcomes of these analyses are reported in the Results section (4.0). In addition, a post-test debrief of the test subjects was conducted. This debrief was used to determine the subjects' attitudes (e.g., acceptance or dislike) toward individual types of TI and the presentation media used. By means of a written questionnaire, subjects were asked to express their reactions, for or against, specific TI characteristics, including style, content, format, delivery medium, and, in general, the ease of use of the TI. It is important to assess which TI characteristics caused the

technicians to view TI as beneficial and easy to use, or — on the other hand — troublesome and confusing. A negative reaction in this category of data might indicate areas where improvement could be required before such a system could be introduced into the Navy. The questionnaire used to obtain the users' reactions appears in Appendix B. This questionnaire includes a scale to allow the respondents to report the intensity of their reactions, negative or positive, on a scale of 1 to 5, to the individual TI characteristics. Subjects were also asked to compare the types of TI for each task and rank them according to their preference.

In addition, each subject was interviewed to allow him to express any opinions not covered by the questionnaire. An outline used to conduct this interview appears as the last page of Appendix B.

4.0 RESULTS

4.1 SUMMARY OF RESULTS

The objectives of the NTIPS Test were as follows:

- o Compare the performance of enlisted maintenance technicians using TI prepared under NTIPS procedures to the performance of technicians using conventional TI (the paper AN/SPA-25D Technical Manual: NAVSEA 0967-LP-445-8010).
- o Compare technicians' performance when using (NTIPS) TI printed on paper to performance using (NTIPS) TI presented via an electronic display device.
- o Establish which design characteristics of NTIPS TI are most effective and least effective in an operational situation.
- o Assess user acceptance of the NTIPS modes (medium, content, format, and style) of TI presentation.

In addition, the Test was designed to provide an evaluation of the NTIPS TI and various aspects of the delivery device in such a way as to indicate the need for improvements or modification in either the TI or in the display system; i.e., the Test was designed to provide a "formative evaluation." The data on subject preference as to various aspects of the NTIPS TI and the use of electronic delivery of TI, have been analyzed, and the results are reported below. The general findings were that a very high percentage (92%) of the subjects preferred electronic delivery of TI over conventional-paper TI presentation. They were able to use NTIPS TI to troubleshoot more accurately and with greater speed, than with the conventional Technical Manual. For Corrective Maintenance, subjects performed at the same accuracy and speed regardless of the type of TI used. A consensus of the comments about NTIPS is as follows:

- o Electronic delivery provides faster and easier access to desired sections of the TI; the technician does not need to look through large volumes of paper. Access can be achieved by one or two keystrokes.
- o FIND is easy to follow; the integration of text and graphics was particularly useful.
- o FIND provides useful guidance to the inexperienced technician.
- o Electronic TI saves space and is easier to update than conventional paper.
- o The computer response time for FIND is too slow; technicians may spend several minutes waiting for the required data to appear.
- o The quality of the Corrective Maintenance TI graphics in any future electronic delivery system must be improved before being implemented in the Fleet.

A more detailed review of these comments is provided in the section on Preference Data (4.4).

4.2 PERFORMANCE TIME AND ACTIONS

As noted, several classifications were established for collecting data describing subjects' actions during the task performance. It was observed that two categories, TI use (TI) and work performance (W), accounted for most of the performance time. Based on this finding, times spent on all other action categories (e.g., communicating, examining the equipment, etc.) were combined and labeled "miscellaneous (M)" for purposes of analysis. Analyses of the performance times were conducted both for troubleshooting and corrective maintenance.

4.2.1 Troubleshooting Performance Times

Two troubleshooting problems were performed by each subject technician. Half of the 24 subjects used FIND and half used the conventional Technical Manual in solving Fault 1; when working on Fault 2 the types of TI were reversed. Thus each subject used FIND and the conventional Technical Manual when performing troubleshooting. In the conventional Technical Manual (if the Fault Logic Diagram is followed), three test points are required to isolate Fault 1 and four test points to isolate Fault 2; in FIND, four test points were selected for Fault 1 and five test points for Fault 2.

The conventional Technical Manual provided several types of data to support troubleshooting. These data were in a variety of formats and were scattered throughout the manual making it necessary for the technicians to flip back and forth. The types of information presented in the conventional Technical Manual include:

- o Table of Contents
- o Troubleshooting index
- o General troubleshooting instructions
- o Signal flow diagrams
- o Schematics including correct waveforms
- o Fault logic diagram (includes fault verification steps)
- o Graphic showing circuit card locations
- o Graphics showing test point locations for each card.

FIND presented an integrated set of procedural steps and graphics (e.g., card locations, test point locations, correct waveforms) for each test point. FIND operates by

interpreting the fault symptoms entered by the subject to select the optimum test point to begin troubleshooting. As the subject technician enters each test result (as satisfactory or unsatisfactory), the FIND system directs the technician to the next most logical test; this process is repeated until the fault is isolated. The specific data presented by FIND for each recommended test are:

- o Control settings on the repeater
- o Oscilloscope settings
- o Circuit card location and test point location
- o Procedural steps
- o Correct waveform graphic.

Table 4 compares the performance times for <u>experienced</u> subjects using NTIPS electronically displayed TI (FIND) with the performance times of subjects using the conventional Technical Manual for troubleshooting Faults 1 and 2. The results for Fault 1 show that the experienced technicians found the fault in 28% less time using FIND than when using the conventional Technical Manual. For Fault 2, the experienced technicians performance time was 16% faster with FIND as compared to the conventional Technical Manual. It may be noted from Table 4 that the major portion of the differences in performance time are in time spent using TI. Troubleshooting performance time could be further reduced by reducing the time the FIND program requires to provide "next step" data to the technician. An analysis of the existing response time shows that approximately 60% of the time attributed to TI use is spent waiting for the next instruction. This time consuming feature of FIND is a function of the current programming of the system and of the speed of the computer used to host the program at this time.

Table 5 compares the performance times for <u>inexperienced</u> subjects using FIND and the conventional Technical Manual for troubleshooting Faults 1 and 2. Performance times for these inexperienced technicians are 30% faster for FIND on Fault 1 and 22% faster for FIND on Fault 2. Most of this difference can be attributed to the amount of time spent using the TI. This is particularly true on Fault 1 where in fault isolation alone subjects spent an average of about 8.5 minutes longer searching through and interpreting the TI in the conventional Technical Manual.

Table 6 summarizes the percentage of time saved using FIND for all subjects. For experienced subjects the time saved is 22%; for inexperienced subjects the time saved is 26%.

Table 4. Troubleshooting mean performance times: experienced subjects

(times in minutes:seconds)

	Fault 1		Fault 2*	
	FIND (6)	Tech. Manual (5)	FIND (5)	Tech. Manual (6)
Verify Fault	4:05	5:00	3:49	6:01
Isolate Fault				
TI	11:27	20:00	13:34	17:30
Work	7:19	8:01	7:47	7:23
Misc	1:00	.	1:57	1:11
Total	23:51	33:01	27:07	32:05

*Excludes data for two instructors who taught this problem at the Fleet Training Center. The total time including these subjects is 24:31.

Table 5. Troubleshooting mean performance times: inexperienced subjects

(times in minutes:seconds)

	Fault 1		Fault 2	
	FIND (6)	Tech. Manual (7)	FIND (7)	Tech. Manual (6)
Verify Fault	3:41	8:00	2:47	7:44
Isolate Fault				
TI	11:32	20:49	13:34	16:35
Work	8:27	6:24	7:06	5:26
Misc	1:00		1:09	1:48
Total	24:40	35:13	24:36	31:33

Table 6. Troubleshooting percentage savings using FIND all faults and all subjects

Subjects	Fault 1	Fault 2	Total Percent Savings Using FIND
Experienced	27.8%	15.5%	21.6%
Inexperienced	29.9%	22.0%	26.0%
Mean Total	28.8%	18.8%	23.8%

4.2.2 Corrective Maintenance Performance Times

Three corrective maintenance tasks were used, each required 7 work steps for removal and 7 work steps for replacement. The tasks consisted of the following:

- o Remove/install Variable Delay Line
- o Remove/install Circuit Card Assemblies
- o Remove/install Support Brackets

Each subject performed all three of these tasks, using a sequence of TI types as shown in Table 3. Data on overall performance times and time spent in each activity were recorded for each corrective maintenance task/TI combination. A review of these data led to the decision to present only those performance time data describing the removal of parts. It was observed that many of the subjects relied on their memories of the removal task and did not use the TI to perform the reinstallation. As a result, it was decided that the installation tasks did not represent a valid test of the TI.

Table 7 shows the corrective maintenance mean performance times for both experienced and inexperienced subjects. The following points can be made with regard to <u>experienced</u> subjects' performance time for each type of TI:

- o Time spent in using the TI was the longest for the conventional Technical Manual, Conv (P) in all three tasks.
- o The best performance times for removal of the Variable Delay Line and the Circuit Card Assemblies were obtained when using the NTIPS paper presentation; the conventional Technical Manual required the greatest amount of time for the Variable Delay Line while the NTIPS electronic delivery required the most time for removal of the Circuit Cards.
- o There were no significant differences in time spent using TI or in total performance time for removal of the Support Brackets.

The time spent by <u>inexperienced</u> subjects in using the different types of TI (first data line) indicates that the conventional Technical Manual (Conv (P)) required the most time for Circuit Card and Support Bracket removal while NTIPS electronically-delivered TI (NTIPS (E)) required the most time for removal of the Variable Delay Line. Within each task the overall performance times for inexperienced subjects were similar for all TI types for removal of Support Brackets and the Variable Delay Line. For the removal of Circuit Cards, using the conventional Technical Manual required 2.65 to 4.3 minutes longer than the two NTIPS presentations.

These results suggest that NTIPS TI is as effective as the conventional Technical Manual when evaluated in terms of corrective maintenance performance time. As will be seen in the discussion of preferences, technicians criticized the graphics in both the paper

Table 7. Corrective maintenance mean performance times (times in minutes:seconds)

Experienced subjects

Activity	Variable Delay Line			Circuit Card Assemblies			Support Brackets		
*	NTIPS (E/4)	NTIPS (P/3)	TM (4)	NTIPS (E/4)	NTIPS (P/3)	TM (4)	NTIPS (E/4)	NTIPS (P/3)	TM (4)
TI	3:27	2:52	5:37	5:54	4:18	7:12	4:46	5:09	5:28
Work	6:12	5:10	6:48	7:42	5:57	5:58	8:20	9:11	6:48
Misc	2:35	2:43	2:55	2:50	1:23	:08	1:38	:58	2:58
Total	12:14	10:45	15:20	16:26	11:38	13:18	14:44	15:18	15:14

Inexperienced subjects

Activity	Variable Delay Line			Circuit Card Assemblies			Support Brackets		
*	NTIPS (E/4)	NTIPS (P/5)	TM (4)	NTIPS (E/4)	NTIPS (P/5)	TM (4)	NTIPS (E/4)	NTIPS (P/5)	TM (4)
TI	5:05	3:06	3:49	5:28	3:50	7:19	3:44	4:15	5:09
Work	4:25	7:24	7:50	6:23	6:24	8:16	8:51	9:44	6:25
Misc	2:38	1:55	1:02	1:30	1:27	:25	1:20	1:48	3:11
Total	12:08	12:25	12:41	13:21	11:41	16:00	13:55	15:47	14:45

*Letters and numbers in parentheses respectively indicate medium of TI delivery and number of subjects.

and electronic versions of NTIPS. The graphics problems are correctable and when improved the technicians' performance when supported by NTIPS should also improve.

4.3 PERFORMANCE ACCURACY

Data collectors recorded two types of accuracy problems while observing the technicians' maintenance performances:

a. Inaccuracies corrected by minor prompts

- o Performance errors of omission and commission, e.g., performed a step out of sequence.
- o Difficulties in interpreting TI or matching TI to equipment, e.g., interpreting a waveform.

b. Inaccuracies corrected by significant assistance

- o Extensive inactivity or work which was irrelevant to the task, e.g., 15 minutes of no work relevant to the task.

Both types of inaccuracy were observed during troubleshooting performance. Only the minor prompt type of performance inaccuracy was noted during corrective maintenance. Separate accuracy analysis results are described below for troubleshooting and corrective maintenance.

4.3.1 Troubleshooting Accuracy

a. Inaccuracies Requiring Significant Assistance. Subjects were given assistance if after 15 minutes of work they had not yet performed any checks or tests relevant to the assigned troubleshooting problem. The judgement as to whether significant assistance was needed was made by Test personnel and was based on the optimum troubleshooting sequences included in FIND and in the conventional Technical Manual. Table 8 presents the number of signficiant assists needed by the technicians using FIND and the conventional Technical Manual to solve the troubleshooting problems. None of the technicians using FIND required signficant assistance to solve their troubleshooting problems. Four of the experienced technicians (36%) and six of the inexperienced technicians (46%) required significant assistance to solve their troubleshooting problem when using the conventional Technical Manual.

b. Minor Inaccuracies Requiring Prompts. Table 9 shows the results of the analysis of this class of performance inaccuracies for troubleshooting. For the technicians using FIND, six of the seven inaccuracies occurred during the work on Fault 2. Four of these prompts involved a problem in locating a circuit card. An analysis of the

Table 8. Signficant assistance needed in fault isolation

	FIND		TM	
	Solved Problem Without help	Needed Help	Solved Problem without help	Needed Help
Experienced	11	0	7	4
Inexperienced	13	0	7	6
	100%	0%	58%	42%

Table 9. Troubleshooting
number of minor prompts

	Subjects	FIND	Tech. Manual
Fault 1	Experienced	1	8
Sweep Resolver	Inexperienced	0	21
Total Fault 1		1	29
Fault 2	Experienced	3	7
Main Gate Generator	Inexperienced	3	3
Total Fault 2		6	10
Total	Both Faults	7	39

work site showed that this inaccuracy occurred when the graphic display on the computer was positioned so that the technicians had to turn 180 degrees from the repeater to see the computer screen. After viewing the screen and returning their attention to the repeater they expected to see a mirror image. As a result they began working on the circuit card on the wrong side of the repeater. This result has implications for the placement of the computer at the worksite.

For the technicians using the conventional Technical Manual, Table 9 shows a total of 39 minor prompts to overcome inaccuracies; 29 of the prompts were given during the Fault 1 problem, and 10 were given during Fault 2. Table 10 subdivides the conventional Technical Manual inaccuracies by type. Three types accounted for 87% of these performance inaccuracies; these types were: (1) interpretation of the Fault Logic Diagram (28%), e.g., the meaning of a question, which path to follow for a particular test result; (2) finding data in the conventional Technical Manual (31%), e.g., finding locator diagrams for cards and test points; and (3) locating cards and test points in the repeater (28%).

To help explain the higher number of inaccuracies in the conventional Technical Manual, Table 11 lists a generic version of the troubleshooting sequences for FIND and for the conventional Technical Manual. The relative ease of using FIND is highlighted by the fact that steps 2 through 6 in FIND are displayed on three separate frames which the technician can link by making a single screen touch or keystroke. On the other hand, the TI to support the equivalent steps in the conventional Technical Manual are contained on 6 to 7 pages (some of which are foldouts), and the technician must search for these pages because they appear in different sections of the manual.

4.3.2 Corrective Maintenance Accuracy

a. Inaccuracies Requiring Significant Assistance. No inaccuracies of this type were recorded during corrective maintenance.

b. Minor Inaccuracies Overcome by Prompts. Table 12 shows the number of minor prompts given to the technicians during corrective maintenance. The minor inaccuracies requiring the prompts were of the following types:

- o Could not locate a part after reviewing the graphics and the procedural steps (False Starts)
- o Omitted a step
- o Worked on the wrong part
- o Performed steps in the wrong sequence
- o Installed a part correctly.

Table 10. Troubleshooting: types of minor prompts needed for technicians using the conventional Technical Manual and FIND

	Prompts	Technical Manual	FIND
1.	Find Fault Logic Diagram	1	
2.	Interpret Fault Logic Diagram	11	
3.	Find Data in Technical Manual	12	
4.	Interpret Schematics	4	
5.	Find Cards/Test Points in Equipment	11	7
		39	7

Table 11. Troubleshooting activity sequence

FIND	Technical Manual
1. Respond to Fault Verification Questions	1. Read Table of Contents
2. Read TI on 1st test point selected by FIND	2. Read troubleshooting index
3. Read oscilloscope set up procedures	3. Locate and read appropriate signal flow diagram or Fault Logic Diagram
4. Read indicator settings/make adjustments	4. Locate and review schematic for test point and waveform
5. Read card location diagram	5. Locate and review card location graphic
6. Read procedures, test point location diagram and correct waveform graphic	6. Locate and review appropriate test point location graphic
7. Perform 1st test	7. Perform test
Repeat steps 2-7 for each test	8. Locate and read signal flow diagram or schematic for correct waveforms
	9. Locate and read appropriate signal flow diagram or the Fault Logic Diagram for the next test
	Repeat steps 4-9 for each test

Table 12. Corrective maintenance types of minor errors

	TI Type					
	NTIPS (E)		NTIPS (P)		Conv (P)	
Error Category	Exp	Inexp	Exp	Inexp	Exp	Inexp
1. False starts	10	7	4	7	5	5
2. Worked on wrong part	3	2		3	--	3
3. Omitted step	--	1	1	1	3	4
4. Performed steps in wrong sequence	1	--	1	1	1	5
5. Installed part incorrectly	1	2	3	1	1	2
TOTALS	15	12	9	13	10	19

Overall, technicans committed 78 minor errors. Thirty-four were made by experienced technicians and 44 were made by inexperienced technicians. Location difficulties accounted for the most errors (rows 1 and 2 accounted for 63% of the total). Comparisons of the total number of errors for each experience group and each type of TI show that:

- o Experienced technicians made more errors when using NTIPS electronically delivered TI than when using the other two types of TI
- o Inexperienced technicians made the largest number of errors when using the conventional Technical Manual.

A frequent comment made by many technicians throughout the corrective maintenance tasks referred to the lack of clarity in the NTIPS graphics and the difficulty in using these graphics to make accurate identifications of parts in the equipment. This point will be discussed in more detail in the section on preference data (4.4).

4.4 PREFERENCE DATA AND TI EVALUATION

A three part preference questionnaire (Appendix B) was completed by all subjects. The first part of the questionnaire asked subjects to indicate their preference for FIND or for the conventional Technical Manual and to rate the features of the electronic delivery system on a scale from 1 to 5, with 1 being poor and 5 being excellent. Subjects were scheduled to respond to this part immediately following their troubleshooting task performance. The second part of the questionnaire asked subjects to rank the three types of TI used for corrective maintenance from most preferred to least preferred. In addition, subjects rated features of the electronic delivery of corrective maintenance TI on a scale from 1 to 5. They were provided with these questions following the corrective maintenance task performance. At the same time subjects were provided with the third part of the questionnaire which requested an overall evaluation and comments.

Following completion of the questionnaire, subjects were debriefed. During the debriefing the following questions were posed to each test subject:

1. If you had a choice of using TI electronically delivered or TI on paper to perform troubleshooting and corrective maintenance tasks, which would you choose?
2. In working with technical documentation, was it easier with the TI electronically delivered or with TI on paper?
3. Which mode of presentation was better organized for your purposes — TI electronically delivered or TI on paper?
4. What do you see as the major advantages of the electronic presentation? Of the paper presentation?

Table 13 summarizes the responses to these questions, broken down by experience level of the technician. These results show that 92% of all technicians preferred electronic to paper delivery of TI based on their experiences during the Test. Additionally, 20 of the 24 subjects indicated that the TI electronically delivered was easier to use and better organized than the technical manual. The technicians identified three major advantages of TI electronically delivered:

- o Provides faster access
- o Eliminates clutter and page flipping
- o Provides guidance for inexperienced technicians

The major advantage of the paper presentation over the electronic delivery were identified as:

- o Schematics are provided in the conventional Technical Manual and not in the current electronic delivery system. Several technicians, particularly those with experience, preferred to use schematics for troubleshooting as compared to a procedural approach.
- o The graphics for corrective maintenance were clearer in the paper presentation than in the electronic presentation.

Table 13. Subjects preference for TI medium paper or electronic delivery

	Experienced		Inexperienced		Total	
	Paper	Electronic	Paper	Electronic	Paper	Electronic
Overall Preference	1	10	1	12	2	22
Easier to Use	2	9	2	11	4	20
Better Organized	2	9	2	11	4	20

The subjects' responses to the preference items in the questionnaire are provided in Tables 14 and 15. Some general findings regarding preference are:

- o <u>For troubleshooting</u>: FIND was preferred to the conventional Technical Manual by all subjects for fault isolation, and by 22 of the 24 subjects for fault verification (Table 14).
- o <u>For corrective maintenance</u>: For step instructions NTIPS electronic was preferred by 63% of the subjects; 17% preferred NTIPS on paper and 20% preferred conventional Technical Manual (Table 15).
- o <u>For corrective maintenance</u>: For graphics paper presentation, either NTIPS or the conventional Technical Manual was preferred by 75% of the subjects (Table 15).

Table 14. Troubleshooting: TI preferences
(number of subjects)

Subjects	Fault Verification		Fault Isolation	
	Technical Manual	FIND	Technical Manual	FIND
Experienced	2	9	--	11
Inexperienced	--	13	--	13
Total	2	22		24

Table 15. Corrective maintenance: TI preferences
(number of subjects)

Subjects	Step Instructions			Graphics		
	NTIPS (E)	NTIPS (P)	Technical Manual	NTIPS (E)	NTIPS (P)	Technical Manual
Experienced	7	2	2	3	5	3
Inexperienced	8	2	3	3	4	6
Total	15	4	5	6	9	9

In addition to indications of preference for the various types of TI used in the test, subjects were asked to rate the information control, the keyboard and the display screen of the electronic delivery system. The information control features include menus and procedures for locating information in the data base; the keyboard features are layout and ease of use; the screen features are brightness, glare, and resolution. Table 16 presents the ratings for these features. The results show that all features were rated as good (the scale was 1-5, with 1 being poor and 4 being good).

Table 16. Ratings for electronic system features
(scale 1 poor – 5 excellent)

Subjects	Information Control		Keyboard	Screen
	FIND	NTIPS (E) (Corrective Main.)		
Experienced	4.0	3.7	4.0	4.0
Inexperienced	4.0	4.1	4.1	4.2

At the end of the questionnaire sections dealing with troubleshooting and corrective maintenance, subjects selected from a list of features of the electronically presented TI those features they liked the most and those they liked the least. The results are shown in Table 17. The same three features were selected by the test subjects as most desirable for the electronically delivered troubleshooting TI and for the electronically delivered corrective maintenance TI. These three features are:

- o The step by step instructions (clarity of text and procedure)
- o The organization of the procedure
- o The relationship of text to graphics on each screen.

The features the subjects liked the least differed for troubleshooting and corrective maintenance. As mentioned earlier, one of the biggest problems with FIND was the slow system response time; approximately 60% of the time spent using the FIND TI involved waiting for the system to process a result or a response and present the next screen of information. The second major problem with FIND, as it currently exists, is the inability to back-up sequentially or to skip over information that is already known by the technician. Both response time and flexibility of procedure are being addressed by the NTIPS staff, and appropriate modifications will be introduced.

For corrective maintenance, the major problems with the electronic TI involved the graphic presentations. Graphics were too small, too hard to read, and in many cases, not oriented properly. In addition, callouts were not always clear. Suggestions made during the test include:

- o Increase graphic size
- o Improve graphic resolution

Table 17. Features of NTIPS TI (electronically presented) selected as most and least liked

	FIND	NTIPS Electronic (Corrective Maintenance)
Most Liked	1. Step by step instructions	1. Step by step instructions
	2. Organization	2. Organization
	3. Relationship of text to graphics	3. Relationship of text to graphics
Least Liked	1. System Response time	1. Size of graphics
	2. Movement around data base	2. Detail of graphics

- o Provide technician with a reference point on the graphic that can be seen easily on the equipment
- o Highlight callouts for each step; have technician indicate the step and then show relevant callouts in a brighter or different color.
- o Provide less text in specific text-graphic modules. This procedure would result in fewer callouts per screen and allow graphics to be larger.

4.5 FLEET TECHNICIANS' SUGGESTIONS ON HOW TO IMPROVE DEVELOPMENTAL NTIPS TI

The fleet technicians participating in the test were asked during a post-test interview what the Navy might do to further improve the electronic devices used to deliver maintenance information. A summary of their suggestions is provided below.

A. Usability of Graphics for Both the Paper and Electronically Delivered Corrective Maintenance Packages

Virtually all participating technicians stated that the graphics for NTIPS corrective maintenance TI were difficult to use. The technicians believed that key equipment-part illustrations were too small and contained too little detail. Paper graphics were only slightly better than graphics delivered electronically. All parts of the NTIPS TI, including graphics for corrective maintenance, were authored once at an NTIPS authoring station, and then mastered for paper and electronic delivery, thus the two types of experimental TI used essentially the same graphics.

B. Response Time for NTIPS Troubleshooting TI

The NTIPS troubleshooting TI (FIND) is designed to be interactive, and as a result is presented only electronically. Also, testing sequences for a given symptom may not be constant over time, e.g., as the system matures, new test times and component failure rates may be input to FIND and the optimum testing sequence for a given failure/symptom may change. The optimum testing sequence is determined by an algorithm whose time to run is excessive, especially in the AT&T 6300 (a result that occurred when FIND was rehosted to the AT&T equipment from the MODCOMP used in the original development of FIND).

As a result of this situation, technicians complained about the slow system response time for NTIPS troubleshooting TI, especially for the Fault Isolation part (FIND).

However, as shown in Table 6, even with this slow response, FIND fault isolation time averaged 24% faster than when using the conventional Technical Manual. Timing the wait and TI display cycles in FIND showed that approximately 60% of the time spent using the TI involved waiting for the machine to respond with the next TI frame.

Improving this software so that the waiting time is reduced to half of what it was during the test will improve FIND's time savings even further. (See below for projected percentage of time saved using FIND.)

Subjects	Fault 1	Fault 2	Total Savings
Experienced	39.90%	40.35%	40.13%
Inexperienced	28.04%	38.60%	33.32%
Total	33.97%	39.47%	36.73%

Thus the percentage of time saved by use of FIND would increase to 37%.

C. Repetition in FIND

In the Fault Isolation part of FIND each test begins with instructions for setting up the test equipment and the system hardware. Invariably, these set ups are the same for successive tests even though, theoretically, they could differ. In the eyes of the technician, the repetition is a waste of time and FIND software should be modified to keep track of and delete this repetition when appropriate.

D. Use of Schematics to Support Troubleshooting

There are two categories of aids to support troubleshooting:

- o proceduralized (step by step instructions which prescribe the required steps in the fault isolation procedure)
- o decision making (technician selects the checks and tests to perform based on his interpretation of the hardware dependencies shown on a schematic).

FIND uses the proceduralized type of aid, but a relatively large percentage of the technicians stated that they would like to see schematics also become a part of the NTIPS troubleshooting TI. This recommendation is consistent with other research results which

indicate that, depending on the level of experience, technicians desire to have a schematic to use exclusively or to use as an adjunct to proceduralized instructions. FIND in its present form includes very small parts of a schematic diagram. Generally, these parts correspond to circuit cards and the partial schematic shows inputs to and outputs from the circuit cards.

E. Animation of Waveform Portrayal

Past research indicates that technicians' have had difficulty using some types of test equipment and interpreting the test equipment outputs. In using FIND, technicians performed well on the set up of the oscilloscope, but experienced some difficulty in assessing waveforms as being good or bad. One of the technicians participating in the test observed that the TI showed the expected waveform as a static picture but that many of the waveforms showed motion when seen on the oscilloscope. He suggested that the electronic display might include animation to help the user in his assessment of these types of waveforms.

F. User Initiated Interaction for Troubleshooting

Some users suggested that they be allowed more flexibility in interacting with the TI rather than being told what to do by the machine. Past research has frequently produced this user complaint about proceduralized instructions and about any automation. This input is related to the users' suggestion to include schematics as part of the troubleshooting information (see item D above).

5.0 CONCLUSIONS

5.1 INTRODUCTION

The NTIPS test and evaluation was conducted in two stages:

1. The preparation of test TI in accordance with NTIPS specifications and by use of an NTIPS-developed automated authoring system.
2. The comparison of technician performance quality resulting from the use of NTIPS and conventional TI in carrying out troubleshooting and corrective-maintenance tasks on an AN/SPA-25D radar repeater. Conclusions drawn from the data collected during both stages are presented in the following sections.

5.2 SUMMARY OF CONCLUSIONS

Results of the NTIPS field test have shown that TI constructed by automated authoring, and according to NTIPS specifications, when applied by fleet technicians in operational maintenance tasks can significantly improve performance (particularly troubleshooting); and that the electronic presentation of maintenance TI is considered superior to paper presentation of TI by 92 percent of experienced and inexperienced technicians.

The tests also provided valuable guidance, both in the area of specifying the most effective TI (e.g., the need for better graphics) and in the area of electronic-presentation approaches, (e.g., system response time). A number of these suggestions have already been incorporated into NTIPS approaches, others will form the basis for further development.

Although it is difficult to generalize from a test involving a small population of technicians working in a specific maintenance area, it appears that fleet technicians will welcome the automated generation and presentation of fault-isolation and corrective-maintenance TI. The TI innovations proposed by NTIPS in TI content, format, style, and organization, even when presented on paper, are as effective and in some cases more effective than conventional paper Technical Manuals.

5.3 CONCLUSIONS REGARDING NTIPS SPECIFICATIONS AND AUTHORING SYSTEM FOR GENERATING TI

In general, the TI contractor was able to follow the NTIPS TI specifications, and was also able to use the TI authoring system to prepare the experimental TI presenting AN/SPA-25D procedures used in the field test. However, experience with this Test has shown that use of an automated authoring system to prepare Navy weapon system TI in no

way reduces the need for a careful contractually mandated quality assurance program. Specific observations recorded during the preparation process are summarized below.

5.3.1 SPECIFICATIONS

No problems were found regarding clarity of specifications. However, test data showed that the contractor experienced consistent problems in carrying out some of the aspects of TI generation required by TI specifications. Since some of the NTIPS approaches to TI generation were entirely new to the TM writers, this was not an unexpected result.

5.3.2 Computer-Assisted Authoring

During the TI generation process, extensive interaction was required between the TI contractor and the developer of the authoring programs due to the radical difference between the automated approach and the manual approach to TI generation with which the contractor was familiar. A contractor was chosen who had little or no experience with TI automation in order to elucidate problems of this nature. The "prompting" feature of the NTIPS automated authoring systems proved not to be particularly effective as designed. The MODCOMP computer used to host the authoring routine has been made obsolete by rapid technological progress in automated authoring.

5.4 Conclusions and Observations Based on Data From Field Test

This section summarizes (1) observations made during the operational field test conducted at the Naval Sea Combat Systems Engineering Station and (2) the conclusions drawn concerning impact of the NTIPS experimental TI on maintenance task performance.

Reactions of test subjects to the various TI features were consistent with results obtained in operational tests made previously by the three services on various kinds of TI content, format, style, medium, and procedural organization (including those obtained in the previous NTIPS field test; see ref. (1)). Special relevance of these reactions to improvement of the NTIPS technology (both TI and presentation methodology) are cited in the following sections.

5.4.1 Different Approaches to TI Use

Several approaches to the use of TI were observed among technicians during the test. A common approach involved a complete review of the procedure by the technician before any steps were performed, instead of reading each step once and then performing

it before moving ahead in the TI. This observation implies that possible benefit would result from providing a browsing mode in the electronic delivery of task instructions; i.e., providing a summary of a sequence of steps (for example, a kind of annotated checklist) as a supplement to complete details for one step at a time.

5.4.2 Troubleshooting Task Performance Time

Both experienced and inexperienced subject-technicians performed troubleshooting faster using FIND than when using the conventional Technical Manual. For experienced subjects the difference in performance time was 22 percent; for inexperienced subjects the difference was 26 percent. These differences can be attributed to two factors. First, FIND integrates all the data needed by a technician to perform a test. The conventional Technical Manual, on the other hand, is organized so that the technician must search for the desired information and flip from one section to another in order to review all the relevant pieces of data. Thus, the information-gathering process involved in using the conventional Technical Manual is extremely time consuming. The second factor influencing differences in performance time is that FIND selects the test points for the technician while the technician is responsible for test-point selection when using the conventional Technical Manual. Selecting an approach and tracking down the procedure involves time; and if the approach is incorrect, then the technician must begin again.

An additional point to be made about FIND is that there is an opportunity to make it even more efficient by increasing the system response time. In the current form of FIND the technician spends 60 percent of his TI use time waiting for the system to present the next information screen (see Section 4.5 B).

5.4.3 Minor Inaccuracies in Troubleshooting

Both experienced and inexperienced technicians required significantly more prompts to overcome minor inaccuracies when using the conventional Technical Manual than when using FIND for troubleshooting. Specifically, the total technician population required 7 prompts with FIND and 39 prompts with the conventional Technical Manual. Few prompts were required with FIND because FIND provides all the necessary information to conduct the tests. The prompts required when the conventional Technical Manual was being used included help in finding data, and help in interpreting the fault logic diagram. These findings demonstrate that the FIND approach is superior to the conventional paper-based approach in terms of performance efficiency and accuracy.

5.4.4 Significant Assistance Required in Troubleshooting

All technicians successfully located both faults without significant prompting when working with FIND; only 58 percent of the technicians found the fault without significant assistance when using the conventional Technical Manual. This finding is attributed to the proceduralization and consolidation characteristics of FIND, e.g., FIND TI prescribes which tests to conduct and presents all the information needed to perform these tests in a small number of text-graphic modules. By contrast, the conventional Technical Manual requires the technician to choose many of the tests and to work with separated "how-to" information.

5.4.5 Corrective Maintenance Performance Time

Overall, the mean corrective maintenance task performance times with the different types of TI did not differ significantly from one another. There were only minor variations at the subtask level. For example, the slowest performance time for experienced technicians was for removing Circuit Card Assemblies while using NTIPS electronically delivered TI (16.5 minutes). The slowest performance time for inexperienced subjects involved removing the Circuit Cards with the conventional Technical Manual (16 minutes). The range of differences in performance times across all subject types and corrective maintenance tasks was 5 minutes 41 seconds. However, the NTIPS graphics for corrective maintenance TI can be improved considerably suggesting that the same performance improvement obtained with FIND can be obtained with the NTIPS corrective TI.

5.4.6 Corrective Maintenance Errors

All technicians completed all corrective maintenance tasks successfully. The total numbers of minor errors made in carrying out corrective maintenance tasks were: with NTIPS TI in paper form (22), with NTIPS TI electronically presented (27), and with conventional Technical Manual (29). The largest portion of these errors (approximately 63 percent) involved failure to identify or locate a part. In most cases this was a result of inadequate graphics in all three TI types. Overall, experienced technicians made fewer errors (34) than inexperienced technicians (44). Again, improvements in the NTIPS graphics should result in significant reduction in error occurrence.

5.4.7 Graphics Detail

Many of the graphics in the NTIPS TI (especially the electronically displayed version) did not show necessary detail and were too small to be of real benefit to the user. The quality of the graphics was below the quality obtainable by modern state of the art computer systems. This defect in the experimental TI resulted in an unnecessarily large number of inaccuracies (looking in the wrong location for a part and identifying the wrong part). High quality graphics are required, especially in terms of size, for future electronic applications. Ultimately, optimization of text-graphics modules involves trade-offs among such variables as (1) the spatial relationships of text to graphics on a given display, (2) the determination of the ideal amount of work prescribed by the instructions in a single frame, (3) the resolution of the display, (4) the field-of-view of the graphic, and (5) the level of detail provided in the graphic. Rules-of-thumb and conventions based on Human Factors Engineering are available for the treatment of all these variables. Appropriate guidance must be incorporated in a clearly interpretable form into future specifications for automated generation of TI.

5.4.8 Research Issues

A number of short range changes and long range research issues were identified during the field test. The short range changes which will have the greatest impact on system performance include: (1) decreasing response time for FIND and (2) increasing size and resolution of graphics in the corrective maintenance TI.

Longer range research issues include:

- o Making use of animation in presenting waveforms and other changeable data
- o Presenting schematics and signal flow diagrams as part of the NTIPS troubleshooting TI
- o Providing a more interactive, user-directed system for test sequencing
- o Exploring the implications of smart software capable of profiting by maintenance experience.

APPENDIX A
DATA COLLECTION FORMS

Faulted Unit: Sweep Resolver 1A7A1B1

TI: Electronic Task: Verification

Subject

Date

Step Description	Time and Activity						Errors
1. Power-ON Indication							
2. 1F1lite							
3. Edgelites							
4. 28vpwrlite							
5. 1F2lite							
6. 1V1 (on crt)							
7. 1V1 Sweep							

TROUBLESHOOTING FORM

Faulted Unit: Sweep Resolver 1A7A1B1
TI: Conventional   Task: Troubleshooting (Page____)

Subject ____________________
Date ____________________

Step Description	Time and Activity						Errors
Unit # ______ Test Point # ____ ____ ____ ____ Unit # ______ Test Point # ____ ____ ____ ____ Unit # ______ Test Point # ____ ____ ____ ____							

4-2.1 Task 1: Remove Tube Focusing Coil IL3

Subtask 2: Remove Variable Delay Line

TI Type________

Subject ____________

Date ____________

Step Description	Time and Activity						Errors
1. Disconnect connector IWIPI from delay line driver amplifier.							
2. Loosen 2 cap screws (coupling clamp).							
3. Remove 8 screws, lock-washers, washers and variable delay line.							
4. Disconnect white (yellow) phone tip from video amplifier TP-7.							
5. Disconnect green wire phone tip from video amplifier TP-1.							
6. Push leads back to grommets (not through).							

CORRECTIVE MAINTENANCE FORM

APPENDIX B

PREFERENCE QUESTIONNAIRE

PREFERENCE QUESTIONNAIRE FOR TROUBLE-SHOOTING

Instructions for Completing Questionnaire

Now that you have done troubleshooting with different forms of technical information (TI), we are interested in your evaluation. First, read the information on this page. Then complete the questionnaires that follow. Be sure to complete every item. Don't leave any items blank.

Your questionnaire responses will not be used to rate your fitness. All of your responses will be kept in total confidence.

Some questions ask you to choose which type of TI (FIND or Conventional) was better for a particular feature. Other questions ask you to rate electronic TI features on a five-point scale from 1 (for Very Poor) to 5 (for Excellent). Use the definitions of the numbers in the scales that are given below to help make your rating decisions.

1 -	VERY POOR	I don't see how the job can be done with this feature the way it is.
2 -	POOR	This feature isn't very good.
3 -	AVERAGE	This feature is O.K.
4 -	GOOD	This feature makes tasks easier/quicker to perform.
5 -	EXCELLENT	This feature is really great.

As you come to the lists of features on the questionnaires, try to remember how much each feature helped or hindered you. Select the rating that corresponds to your judgment, and mark it on the questionnaire.

Use the COMMENTS column at the right of rating scales or at the end of it to note any strong feelings about a feature or to suggest how it might be improved.

After you have completed the rating section you will be given a list of all features of electronic delivery and asked to check the three best and the three worst. Be sure to complete the BIOGRAPHICAL section at the end of the questionnaire.

If you have any questions, ask a data collector for help.

1. Check the type of TI which was superior on each characteristic.

Information Characteristics	Troubleshooting TI FIND	Troubleshooting TI Conventional
FAULT VERIFICATION		
a. Clarity of symptom questions	_____	_____
b. Completeness of sympton questions	_____	_____
c. Ease of initiating fault isolation steps	_____	_____
d. Presentation format	_____	_____
Fault Isolation		
a. Ease of selecting initial and next tests	_____	_____
b. Ease of card location	_____	_____
c. Ease of test point location	_____	_____
d. Ease of interpretation of test results	_____	_____

2. Please rate the following electronic system features

ELECTRONIC SYSTEM FEATURES
FIND

Electronic System Features	Scale Values 1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
Techniques for Controlling Information Delivery						
1. Ease of using menus to obtain maintenance information	____	____	____	____	____	____________
2. Ease of returning to the appropriate section in a set of procedures after branching to obtain additional information	____	____	____	____	____	____________
3. Adequacy of features to exit from an inappropriate section of the data base (e.g., following an incorrect key press or equipment malfunction)	____	____	____	____	____	____________
4. Adequacy of "prompts" on the display for assisting/guiding the operator	____	____	____	____	____	____________
Features of FIND TI						
1. Format of Text	____	____	____	____	____	____________
2. Level of procedure detail	____	____	____	____	____	____________
3. Sequence of tests	____	____	____	____	____	____________
4. Validity of tests	____	____	____	____	____	____________
5. Legibility of graphics	____	____	____	____	____	____________
6. Understandability of graphics	____	____	____	____	____	____________
7. Size of graphics	____	____	____	____	____	____________

Features of Touch-Sensitive Screen Operation	____	____	____	____	____	__________
1. Arrangement of touch labels	____	____	____	____	____	__________
2. Location of touch labels	____	____	____	____	____	__________
3. Readability of touch labels	____	____	____	____	____	__________
4. Responsiveness of system to using touch labels	____	____	____	____	____	__________

3. Piease check the three Best and three Worst characteristics of the electronic information delivery system you used for Troubleshooting.

BEST AND WORST CHARACTERISTICS OF ELECTRONIC DELIVERY OF TECHNICAL INFORMATION

	Characteristic	Best	Worst
1.	Step by step text		
2.	Organization of procedures		
3.	Relation of text to graphics		
4.	Size of text characters		
5.	Font (letter style)		
6.	Spacing and layout		
7.	Size of graphics		
8.	Number of graphics		
9.	Nearness of graphic to related text		
10.	Detail of graphic		
11.	Graphic callouts		
12.	Touch screen		
13.	Size of touch boxes		
14.	Dependability of touch		
15.	Size of the electronic display		
16.	Electronic display legibility		
17.	Electronic display brightness		
18.	Electronic display glare		
19.	Printer		
20.	Menus		
21.	System response time		
22.	Ability to move around in the data base		

Thanks a lot. If we missed any characteristics that you believe to be important, pro or con, jot them down below.

PREFERENCE QUESTIONNAIRE FOR CORRECTIVE MAINTENANCE

Now that you have completed Corrective Maintenance with three different types of TI (NTIPS (E), NTIPS (P), Conventional paper), we are interested in your evaluation.

Some of the questionnaire items ask you to rank the three TI types on various features (1 being most preferred); others ask for ratings on a five point scale. As with the troubleshooting questionnaire you are also asked to indicate the three best and the three worst characteristics of electronic delivery as it relates to the presentation of Corrective Maintenance TI.

Your questionnaire responses will not be used to rate your fitness. All your responses will be kept in total confidence.

1. Please rate the TI you used for setting up the corrective maintenance process.

TECHNICAL INFORMATION

Type of TI: NTIPS(P); NTIPS(E); Conventional

Information Characteristics	Strength of Approval or Disapproval 1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
CORRECTIVE MAINTENANCE TI						
1. Introductory Discussion	____	____	____	____	____	________
2. Setup Instructions						
a. "Applicable Configuration"	____	____	____	____	____	________
b. Test Equipment	____	____	____	____	____	________
c. Tools	____	____	____	____	____	________
d. Materials/Parts List	____	____	____	____	____	________
e. Task References	____	____	____	____	____	________
f. Personnel Required	____	____	____	____	____	________
g. Special Skills and Knowledges	____	____	____	____	____	________
h. Approximate Time Required	____	____	____	____	____	________
i. List of Directives	____	____	____	____	____	________
3. General Safety Instructions	____	____	____	____	____	________
SUPPORT TI						
1. Table of Contents	____	____	____	____	____	________
2. IPB	____	____	____	____	____	________
3. Preparatory Instructions	____	____	____	____	____	________
a. Indicator Preparation	____	____	____	____	____	________
b. Task Preparation	____	____	____	____	____	________
4. Others (describe)						

2. Please rank the three types of TI for each characteristic.

Information Characteristics	Corrective Maintenance TI NTIPS (E)	NTIPS (P)	Conventional Work Package
1. Step Instructions			
a. Organization into Tasks, Subtasks, and Steps	____	____	____
b. Amount of text	____	____	____
c. Usability of text	____	____	____
- Level of Detail	____	____	____
- Format	____	____	____
- Clarity of Writing	____	____	____
2. Graphics			
a. Amount of Graphics	____	____	____
b. Usability of Graphics	____	____	____
- Legibility	____	____	____
- Understandability	____	____	____
- Size	____	____	____
- Ease in Finding Components	____	____	____
- Level of Detail	____	____	____
- Format	____	____	____

3. Please rate the following electronic system features.

ELECTRONIC SYSTEM FEATURES
CORRECTIVE MAINTENANCE

Electronic System Features	Scale Values 1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
Techniques for Controlling Information Delivery						
1. Ease of using menus to obtain maintenance information	____	____	____	____	____	________
2. Ease of returning to the appropriate section in a set of procedures after branching to obtain additional information	____	____	____	____	____	________
3. Adequacy of features to exit from an inappropriate section of the data base (e.g., *following* an incorrect key press or equipment malfunction)	____	____	____	____	____	________
4. Adequacy of "prompts" on the display for assisting/guiding the operator	____	____	____	____	____	________
Features of Touch-Sensitive Screen Operation	____	____	____	____	____	________
1. Arrangement of touch labels	____	____	____	____	____	________
2. Location of touch labels	____	____	____	____	____	________
3. Readability of touch labels	____	____	____	____	____	________
4. Responsiveness of system to using touch labels	____	____	____	____	____	________

4. Please check the three Best and three Worst characteristics of the electronic information delivery system you used for Corrective Maintenance.

BEST AND WORST CHARACTERISTICS OF ELECTRONIC DLLIVERY OF TECHNICAL INFORMATION

	Characteristic	Best	Worst
1.	Step by step text		
2.	Organization of procedures		
3.	Relation of text to graphics		
4.	Size of text characters		
5.	Font (letter style)		
6.	Spacing and layout		
7.	Size of graphics		
8.	Number of graphics		
9.	Nearness of graphic to related text		
10.	Detail of graphic		
11.	Graphic callouts		
12.	Touch screen		
13.	Size of touch boxes		
14.	Dependability of touch		
15.	Size of the electronic display		
16.	Electronic display legibility		
17.	Electronic display brightness		
18.	Electronic display glare		
19.	Printer		
20.	Menus		
21.	System response time		
22.	Ability to move around in the data base		

Thanks a lot. If we missed any characteristics that you believe to be important, pro or con, jot them down below.

5. Please complete the following questions based on your experience with both troubleshooting and corrective maintenance TI.

ELECTRONIC SYSTEM FEATURES: GENERAL

Electronic System Features	Scale Values 1 Very Poor	2 Poor	3 Avg	4 Good	5 Exc	Comments
Features of NTIPS Keys and Keyboard						
1. Spacing of keys	____	____	____	____	____	________
2. Arrangement of keys	____	____	____	____	____	________
3. Ease of operating keys	____	____	____	____	____	________
4. Indication(s) that keys have been activated	____	____	____	____	____	________
5. Reliability of keys (i.e., how well did the keys respond to use)	____	____	____	____	____	________
General Screen Features						
1. Adequacy of screen size for display of information	____	____	____	____	____	________
2. Brightness of display	____	____	____	____	____	________
3. Readability of display screens	____	____	____	____	____	________
4. Contrast between displayed information and background	____	____	____	____	____	________
5. Glare resistance of display screen	____	____	____	____	____	________

GENERAL COMMENTS

1. If you had a choice of using an electronic or paper-based manual to perform tasks which would you choose?____________________

2. In working with the technical documentation, was it easier with the electronic device?__________ Or paper?__________

3. Which mode of presentation was better organized for your purposes? Electronic?__________ Or paper?__________

4. What do you see as the major advantages of the electronic presentation?

The paper presentation?

APPENDIX C

EXAMPLES OF TECHNICAL INFORMATION

FIND FAULT VERIFICATION PROCEDURES

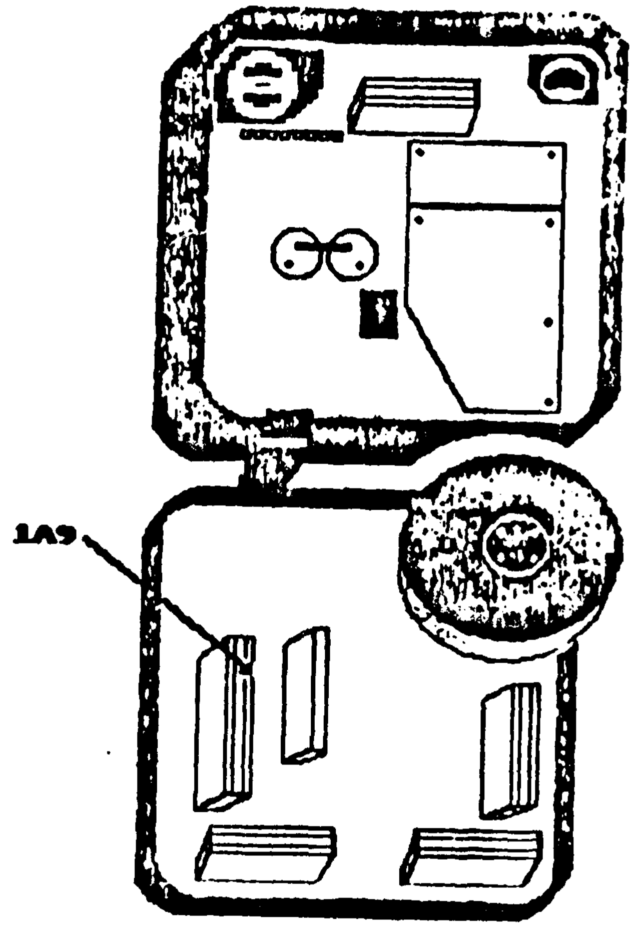
#	Fault Symptom Description	True Statement?	
a 1	Is POWER ON indicator light lit?	YES	NO
b 2	Is 115vac fuse indicator light off? (Should never be on when answer to question 1 is YES; POWER ON indicator light is lit.)	YES	NO
c 3	Are front panel edgelights on?	YES	NO
d 4	Is 28vac POWER indicator light lit?	YES	NO

Press corresponding letter ("#" column) or touch box to select Symptom

Scrolling Options	User Assistance	Load Data from Fault Verification	Begin Troubleshooting Session
-BACK- Backward / -NEXT- Forward	-HELP-	-LAB-	-DATA-

FIND CARD LOCATOR

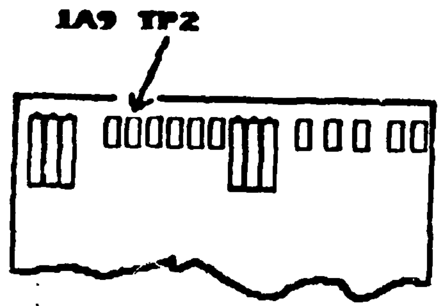
The NS switched sweep data signal is an output of the video cursor sweep switch circuit card, 1A9.



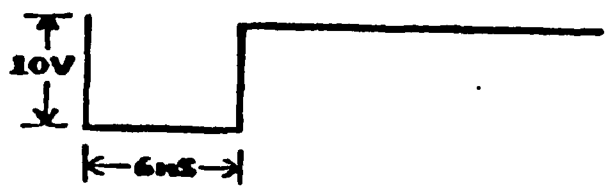
NEXT PAGE | BACK PAGE | COPY PAGE | HELP | STOP/EXIT

FIND TEST PROCEDURES

Connect oscilloscope probe to TP2 on the video cursor sweep switch circuit card, 1A9.



INDICATION: A negative square wave when the VIDEO SWEEP is rotating is GOOD.

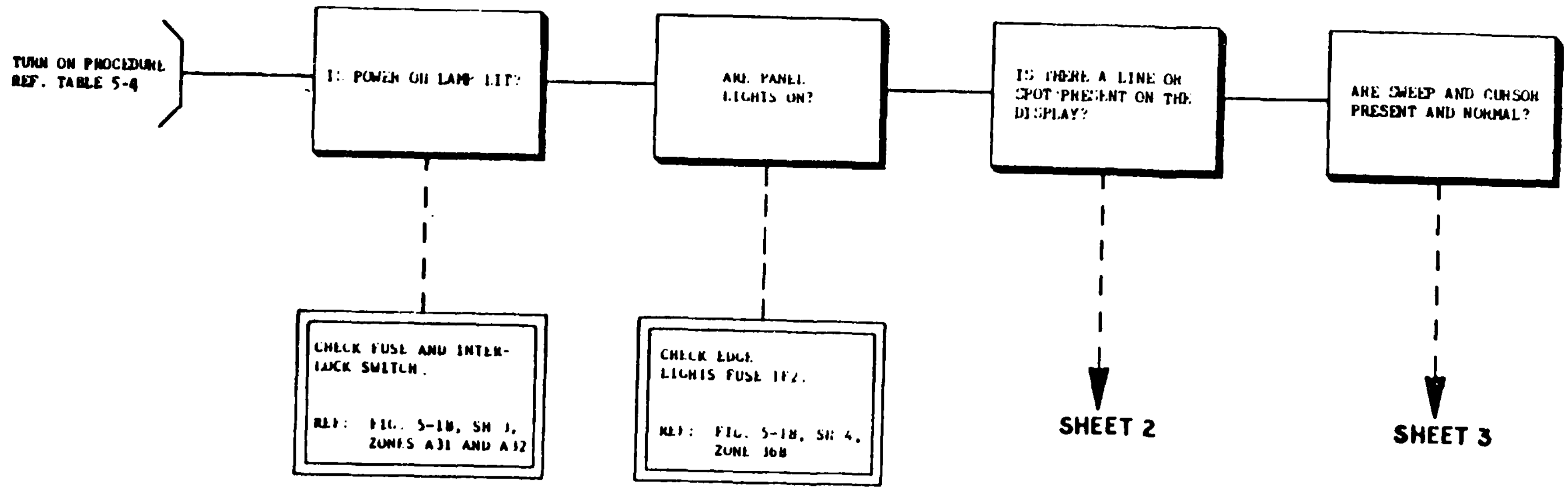


Select y(YES) to set result GOOD or n(NO) to set result BAD.

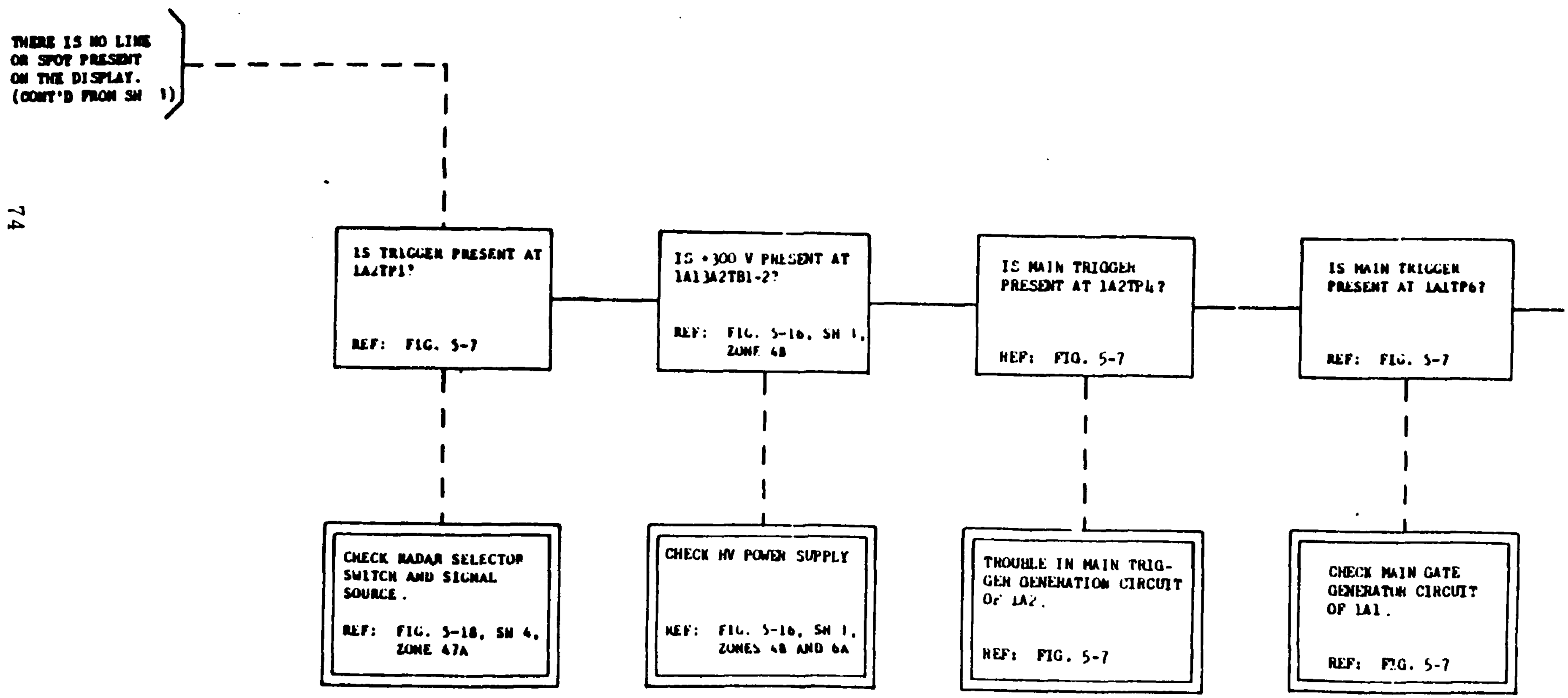
BACK PAGE	y(YES)	n(NO)		COPY PAGE	HELP	STOP/EXIT

CONVENTIONAL TECHNICAL MANUAL— FAULT LOGIC DIAGRAM

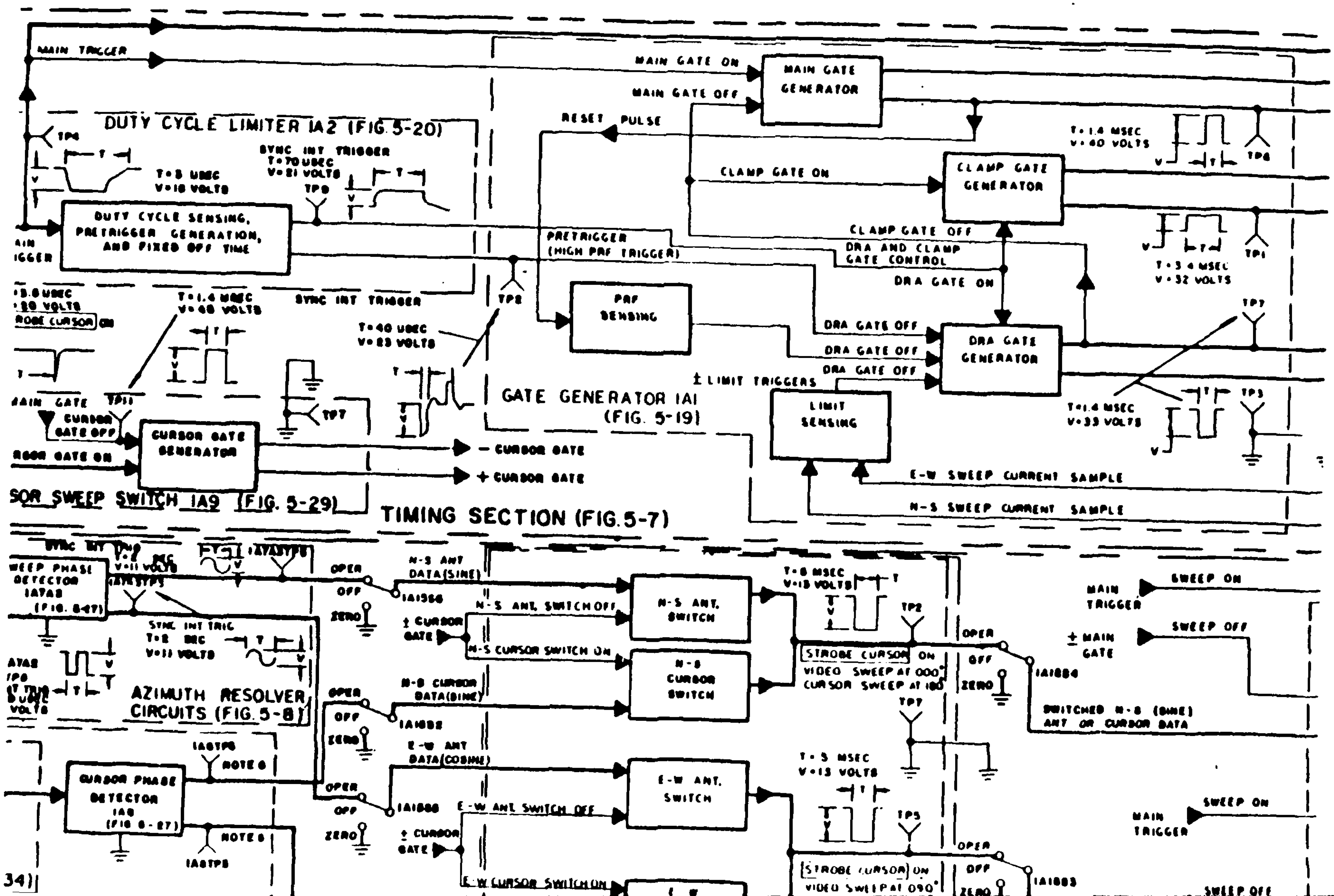
(SHEET 1 OF 9, PARTIAL)



CONVENTIONAL TECHNICAL MANUAL— FAULT LOGIC DIAGRAM
(SHEET 2 OF 9, PARTIAL)



CONVENTIONAL TECHNICAL MANUAL—SIGNAL FLOW DIAGRAM (PARTIAL)



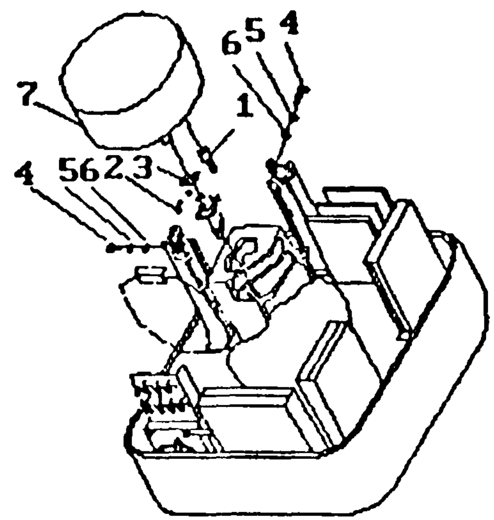
NTIPS ELECTRONIC — CORRECTIVE MAINTENANCE (SCREEN PRINT)

4-2.1. S12. REMOVE VARIABLE DELAY LINE 1A14A2

1. Disconnect connector 1W1P1 (1) from delay line driver amplifier 1A14A1.

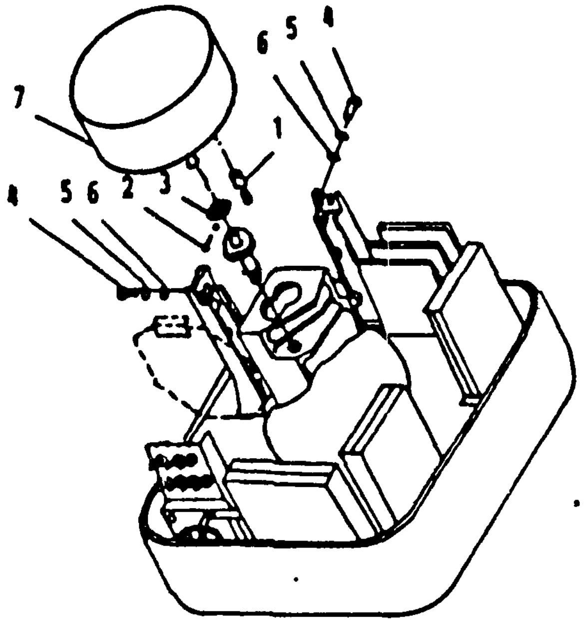
2. Loosen two cap screws (2) in coupling clamp (3).

3. Remove six screws (4), lockwashers (5), and flat washers (6). Remove variable delay line 1A14A2 (7).



NEXT PAGE					COPY PAGE	HELP	STOP/EXIT

4-2.1. ST2. REMOVE VARIABLE DELAY LINE 1A14A2



1. Disconnect connector 1W1P1 (1) from delay line driver amplifier 1A14A1.
2. Loosen two cap screws (2) in coupling clamp (3)
3. Remove six screws (4), lockwashers (5), and flat washers (6). Remove variable delay line 1A14A2 (7).

CONVENTIONAL PAPER: CROSS REFERENCE AND PAGE-TURNING

6-38. 1V1 CATHODE RAY TUBE (figure 6-2). To remove, install, and adjust cathode ray tube (crt), proceed as follows:

1.

2.

3.

4. Disconnect the delay line driver connector (2, figure 6-2) from the delay line driver circuit board.

5. Loosen the two coupling clamp cap screws (1).

6. Remove the six variable delay line mounting screws, lockwashers, and flat washers (4) and remove the variable

igure 6-2. Crt Disassembly (Sheet 1 of 2)

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